IN-HOUSE PRODUCTION OF A LARGE-GRAIN SINGLE-CELL CAVITY
AT CAVITY FABRICATION FACILITY AND RESULTS OF
PERFORMANCE TESTS

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Abstract

Processes of in-house production of a large grain single-cell cavity and results of performance tests are reported. EBW tests by using test pieces cut out from large grain Nb disks were carried out before the equator welding. The results were consistent with those of fine-grain Nb test pieces. An actual situation of equator welding, however, was different from that expected at EBW tests, because of the large errors of equator thickness due to the difficulty of machining a large grain Nb. As a result, a bead-width distribution contains large errors reflecting those of equator-thickness. The completed cavity was named KEK-R1, and its performance tests were carried out. The accelerating gradient of the cavity exceeded 45 MV/m. The maximum values of Q-factor at the first test achieved $10 \times 10^{10}$ and $2 \times 10^{10}$ at very low temperature and 2.0 K, respectively, and those at the second test achieved $6 \times 10^{10}$, $5 \times 10^{10}$, $4 \times 10^{10}$, $3 \times 10^{10}$ and $2 \times 10^{10}$ at 1.4 K, 1.6 K, 1.7 K, 1.8 K and 2.0 K, respectively.

INTRODUCTION

Cavity Fabrication Facility (CFF) is a facility of KEK for studying technologies of the mass production of superconducting radio-frequency (SRF) cavities, where a press machine, a vertical lathe, a chemical room with a fume hood and an electron-beam welding (EBW) machine are all equipped in one clean environment. In CFF, fine grain (FG) Nb sheets have been used as a material of SRF cavities rather than large grain (LG) Nb disks [1]. Cavities made from LG-Nb disks, however, have attracted much attention of researchers of this field for the last decade because of their higher Q-factors compared to those made from FG-Nb sheets. A possibility of mass production of LG-Nb cavities is worth studying toward a future accelerator-project. At CFF, the in-house production and studies of fabrication technology of a LG-Nb cavity started last year. The completed cavity was named KEK-R1, and its performance tests were carried out this year. In this paper, processes of the production and results of performance tests are briefly reported.

EBW TEST

LG-Nb disks with diameters 270 mm and thicknesses 3.18 mm were supplied from Tokyo Denkai (Fig. 1(a)). Test pieces with 150 mm × 150 mm and 150 mm × 22 mm were cut out from the disks. The former was for the bead-on-plate welding and the latter was for the butt welding. Both types of test pieces had rectangular areas with thickness 2.0 mm, which imitates the equator thickness. These test pieces were cut to the chemical room of CFF and etched by the buffered chemical polishing (BCP) solutions, where 10-30 μm of materials were removed. Following ultrapure water rinsing and natural drying, the test pieces were car-

Figure 1: (a) LG-Nb disk supplied from Tokyo Denkai. (b) Half-cell with a copper shell. (c) Trimmed half-cell.

Figure 2: Results of EBW tests. Orange symbols are results of FG-Nb test pieces obtained before. Green and blue symbols are results of LG-Nb test pieces, where the former and latter correspond to bead-on-plate welding and butt welding, respectively. Circles correspond to good welds. Squares correspond to narrow weld beads or non full-penetrating-welds. Crosses correspond to weld beads with holes or spatters.
Fabrication

First the LG-Nb disks were machined into concentric disks by wire electrical discharge machining. The concentric disks were carried to CFF and layered with copper disks to fit the existing press-dies, then pressed into half-cells (Fig. 1(b)). The half-cells were machined into male and female by trimming the outside of the equator and both the inside and the outside of the equator, respectively, where

1The \( a_b \)-factor is defined by \( a_b \equiv \ell/f \), where \( f \) is a focal length of a magnetic lens and \( \ell \) is a distance between a center of magnetic lens and a test piece. \( a_b = 1 \) and \( a_b \neq 1 \) correspond to a focused and defocused beam, respectively. Details of EBW parameters are found in Ref. [2].

Welds of half-cells and beam pipes were carried out by an EBW machine equipped in machine shop in KEK, which is different machine from that of CFF.

The design thicknesses of machined tips are both 1.0 mm, and thus that of joint of the male and the female is 2.0 mm. The copper shells were detached at this stage (Fig. 1(c)). Following BCP, ultrapure water rinsing and natural drying in the chemical room, the trimmed half-cells were EB welded with beam pipes made from FG-Nb sheets (Fig. 3).

Before welding the equator, thicknesses of joint parts of the male and the female were measured by a caliper. Figure 4 shows their thicknesses as functions of position in degree. The thickness distribution of the female was close to the target thickness, 1.0 mm. On the other hand, that of the male had large errors \( \sim 20\% \). As a result, the summations of two thicknesses, which correspond to thicknesses of material to be welded, had 10% errors from the design value, 2.0 mm. These errors made a choice of EBW parameters difficult: since the EBW test was carried out by using the test pieces with thickness 2 mm, there was possibilities of inducing poor welds at thicker regions and holes at thinner regions due to deficiencies and excesses of the energy deposition, respectively. Taking into account that the cavity has a larger heat capacitance than the test pieces, we chose...
from room temperature to 5 K, then increased up to 17 K, and decreased down to a very low temperature, at which the vapor pressure thermometer showed negative values indicating outside of calibrated range. Following the test at a very low temperature, the cavity temperature was increased again, and the test at 2 K was also carried out. In the second test, the cavity temperature was monitored by both the vapor pressure thermometer and two silicon thermometers put on the beam-pipes, which were calibrated in a range $T > 1.5$ K. The cavity temperature was decreased down to 2 K, and tests at 2 K, 1.8 K, 1.7 K, 1.6 K, and 1.4 K were carried out. Note that 1.4 K is out of the calibrated range of the silicon thermometers. The results of first and second tests are shown in Fig. 7. The accelerating gradient of the cavity exceeded 45 MV/m. The maximum values of Q-factor at the first test achieved $10 \times 10^{10}$ and $2 \times 10^{10}$ at very low temperature and 2 K, respectively, and those at the second test achieved $6 \times 10^{10}$, $5 \times 10^{10}$, $4 \times 10^{10}$, $3 \times 10^{10}$ and $2 \times 10^{10}$ at 1.4 K, 1.6 K, 1.7 K, 1.8 K and 2.0 K, respectively.

Surface resistances $R_s$ as functions of inverse of temperature and residual resistances $R_{res} \equiv \lim_{T \rightarrow 0} R_s$ for every $E_{acc}$ value can be extracted from the results, and field dependences of BCS and residual resistances can be evaluated [4, 5]. Analyses are in progress and will be presented elsewhere.

**SUMMARY**

We started the in-house production and studies of fabrication technology of a LG-Nb cavity last year. According to the EBW tests with LG-Nb test-pieces, the optimum EBW parameters for LG- and FG-Nb are consistent. EBW parameters that have been searched so far by using FG-Nb test pieces might be used in equator welding of LG-Nb cavities. Difficulty in equator welding of LG-Nb cavity is caused by the large errors of equator thickness due to the difficulty of machining a large grain Nb, which make choices of EBW parameters difficult. Even if the equator welding is succeeded, a bead-width distribution might contain large errors reflecting those of equator-thickness like that of KEK-R1. Improvements of machining processes are essential.

**REFERENCES**